CLAIMS

1. A method of designing a two-mirror high numerical aperture imaging device comprising the steps of:

(a) determining the positioning of each consecutive point of a cross-section through the *x*-axis of a first mirror and a second mirror, iteratively for a cross-section in the plane $z = 0$, where the *x* and *y* coordinates of each successive point on the two mirrors in the cross-section are $M_1(t) \equiv (m_{1,x}(t), m_{1,y}(t), 0)$ (for the first mirror) and $M_2(t) \equiv (m_{2,x}(t), m_{2,y}(t), 0)$ (for the second), *t* being an iteration counter; where the functions $M_0(t) \equiv (m_{0,x}(t), m_{0,y}(t), 0) \equiv (f, 0, 0)$ and $M_3(t) \equiv (m_{3,x}(t), m_{3,y}(t), 0) \equiv (0,0,0)$ are set to define the centres of the object and image planes respectively

(b) Calculating the angle $d_i(t)$ (for $i = 0, \ldots, 2$) that a ray from $M_i(t)$ to $M_{i+1}(t)$ makes to the *x*-axis, i.e.

$$d_i(t) = \arctan\left(\frac{m_{i+1,y}(t) - m_{i,y}(t)}{m_{i+1,x}(t) - m_{i,x}(t)}\right)$$

(c) Calculating the distance $p_i(t)$ (for $i = 0, \ldots, 2$) between $M_i(t)$ and $M_{i+1}(t)$, i.e.

$$p_i(t) = \sqrt{(m_{i+1,x}(t) - m_{i,x}(t))^2 + (m_{i+1,y}(t) - m_{i,y}(t))^2}$$

(d) Calculating the angle $a_i(t)$ that a tangent to the *i*'th surface makes to the *x*-axis, taking $a_0(t)$ and $a_3(t)$ to be the angles that the object and image planes make to the *x*-axis (being 90° for all *t* for the surfaces to be rotationally symmetric about the *x*-axis), i.e. for reflection (for $i = 1$ and 2):

$$a_i(t) = \frac{d_i(t)}{2} + \frac{d_{i-1}(t)}{2}$$

(e) Choosing the values of $m_{i,x}(0)$ and $m_{i,y}(0)$ (for $i = 1$ and 2) so that the resulting mirror layout satisfies the sine criterion. For a far away source (say along the negative *x*-axis, say $f = -10^9$) a scale parameter, *b* may be set equal to unity (without loss of generality, such that $B = b/p_0(0) = 1/p_0(0)$). The sine criterion is then satisfied if:

$$m_{1,y}(0) = \pm \frac{m_{2,y}(0)}{(m_{2,x}(0)^2 + m_{2,y}(0)^2)^{1/2}}$$

(f) Iterating either from shallower angles to more oblique angles, or vice versa (switching between the two being achieved by using as seed values later iterated results and reversing the sign of the iteration step size *h*). If the iteration is from highly oblique angles then set $m_{2,x}(0)$ equal to a small number close to zero, say 10^{-9}, and choose $m_{1,x}(0) = q_1$ and $m_{2,y}(0) = q_2$, where q_1 and q_2 are arbitrary real numbers (positive or negative), but with the choice of signs of q_1, q_2 and *h* constrained so as <u>not</u> to have simultaneously the sign of q_1 negative, the sign of q_2 positive and the sign of *h* positive. Then $m_{1,y}(0)$ will

need to be ±1 for the initial parameters to satisfy the sine criterion. Without loss of generality it is possible to choose $m_{1,y}(0)$ to be -1.

(g) Choosing the sign Z so that the sine criterion remains satisfied as t changes.

(h) Updating the values of $M_i(t)$ as follows (for a small value of h):

$$M_i(t+1) \equiv \begin{pmatrix} m_{i,x}(t+1) \\ m_{i,y}(t+1) \end{pmatrix} = M_i(t) + w_i \begin{pmatrix} \cos(a_i(t)) \\ \sin(a_i(t)) \end{pmatrix} h$$

where $r_{i-1}(t) = \sin\left(a_{i-1}(t) - d_{i-1}(t)\right)$ $s_i(t) = \sin\left(a_i(t) - d_{i-1}(t)\right)$ and where

$$w_2 = \frac{p_1 r_0}{p_0 s_2} \quad w_1 = -ZB\frac{p_1 s_3}{p_2 r_1}$$

(i) Ending the iteration no later than when light rays cease to be able to pass freely through the mirror arrangement, once it has been rotated as in (j).

(j) Rotating the curves produced above around the x-axis to define the complete, three-dimensional mirror surfaces.

2. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $-1 < q_2 < 0$ and $h < 0$.

3. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $0 < q_2 < 1$ and $h > 0$.

4. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $0 < q_2 < 1$ and $h < 0$.

5. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $-1 < q_2 < 0$ and $h > 0$.

6. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $0 < q_2 < 1$ and $h < 0$.

7. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $-1 < q_2 < 0$ and $h > 0$.

8. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $-1 < q_2 < 0$ and $h < 0$.

9. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $q_2 > 1$ and $h > 0$.

10. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $q_2 > 1$ and $h < 0$.

11. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $q_2 < -1$ and $h > 0$.

12. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 > 0$, $q_2 < -1$ and $h < 0$.

13. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $q_2 > 1$ and $h < 0$.

14. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $q_2 < -1$ and $h > 0$.

15. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $q_1 < 0$, $q_2 < -1$ and $h < 0$.

16. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which $m_{1,y}(0)$ is chosen (without loss of generality) as equal to -1, and $Z = \mathrm{sgn}(m_{2,y}(0))$.

17. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which the values of q_1, q_2 and h are selected such that the first and second mirrors are on opposite sides of the focal plane of the device.

18. A method of designing a two-mirror high numerical aperture imaging device according to claim 1 in which the values of q_1, q_2 and h are selected such that the focal plane of the device will be closer to an object to be imaged than either of the first or second mirrors.

19. A high numerical aperture imaging device comprising at least two mirrors conforming with the design specifications according to claims 1 to 18.

20. A low mass high numerical aperture imaging device (1) according to claim 19 comprising first and second axially symmetric curved mirrors (1a, 1b) adapted to concentrate sunlight, further comprising a solar thermal propulsion arrangement (1c) that creates direct thrust for powered flight by heating and expelling a propellant.

21. A partially solar-powered orbital launch vehicle comprising a device according to claim 20 and further comprising one or more conventional chemical rockets or jet engines

22. A device according to claim 20 in which the speed at which the propellant is expelled is enhanced by further heating the propellant after it has passed through the rocket throat and as it is passing through the rocket nozzle.

23. A low mass high numerical aperture imaging device (2) according to claim 19 comprising first and second axially symmetric curved mirrors (2a, 2b) adapted to create thrust in outer space by focusing incoming light photons into a small area, further comprising one or more mirrors (2c) that are used to deflect the focused light photons in a suitable direction away from the device, the thrust being generated by the deflection of the photons.

24. A high numerical aperture imaging device according to claim 19 adapted to concentrate electromagnetic radiation to a high temperature for the purpose of generating electric power.

25. A low mass device according to claim 24 adapted to generate electric power and to provide thrust for powered flight.

26. A low mass device according to claim 25 in which the thrust is provided by a balanced ion drive in which both positively and negatively charged ions are simultaneously propelled away from the device in suitable proportions to avoid a space charge building up around the device.

27. A low mass device according to claim 24 in which the mirrors are provided in or on an inflated balloon.

28. A high numerical aperture imaging device according to claim 19 comprising first and second axially symmetric curved mirrors for focusing the image of an object onto an image point, wherein the first and second curved mirrors are arranged to effectively create inwardly imploding dipole-like solutions to the applicable wave equation, to concentrate the energy flux arriving at the image plane from a given point in the object more than would be possible were the image formation to be subject to the diffraction limits that generally apply to far field devices.

29. A high numerical aperture imaging device according to claims 19 or 28 further comprising a partially transparent plane mirror positioned proximate to the image plane.

30. A device according to claims 19, 28 or 29, further comprising a wave attenuation element and a wave polarisation-rotating element designed so that the spatial distribution of the amplitude and polarisation of a wavefront as it approaches the image plane is rendered more closely consistent with that required to generate dipole-like solutions to the wave equation.

31. A device according to any of claims 19, 28, 29 or 30, adapted to produce highly accurate lithographic images for use in semiconductor/microchip manufacture.

32. A device according to claim 19 adapted to concentrate or project light, or other waves, or physical entities (other than waves) satisfying equivalent 'ballistic' equations of motion.

33. A device according to claim 19 in which the first and second mirrors are not inherently structurally rigid, and are adapted to rotate about a common axis in operation in order to maintain their required shape.

34. A device according to claim 19 in which the first and second mirrors are not inherently rigid, and are adapted to be inflated in operation to attain their required shape.

35. A device according to claim 19 for interlinking of optical networking components, the device further comprising a solid state optical emitter or detector in the source/image plane, "optical" here to be understood to include infra-red, microwave and other sorts of electromagnetic radiation as well as visible light.

36. A device according to any of claims 19 to 35 in which the shape of the first and second mirrors is further modified to compensate for higher order aberrations by adjusting $M_0(t)$ and $M_3(t)$ in step (a) of claim 1 so that the centres of images of edges of a suitably sized circular or far away spherical object are at each step of the iteration more nearly centred on the point at which rays from the centre of such a circular or far away spherical object would strike the image plane.

37. A high numerical aperture device according to any of claims 19 to 36 further comprising one or more additional mirrors and/or refracting or diffracting surfaces, adapted to exhibit improved aberration characteristics.